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Evaluation of Treatment Tables for Severe Decompression Accidents

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Introduction

This paper describes the requirement for an in-depth analysis of the treatment of a severe decompression accident following a rapid, uncontrolled ascent during deep diving operations using the “Canadian Underwater Minecountermeasures Apparatus” (CUMA).

Background

The risk of a serious decompression accident is of great concern for divers using a self-contained, mixed-gas breathing apparatus such as the CUMA. While such incidents are rare, more dives are being conducted worldwide by military, commercial and technical divers using similar apparatus. Dives can be conducted at deep depths (greater than 50 metres of seawater, maximum 81 metres of seawater (msw)), breathing helium and oxygen mixtures. Unlike surface-supplied divers, CUMA divers are untethered, free swimming and subject to more variables which can effect buoyancy and ascent rates.

If a rapid or uncontrolled ascent to the surface occurs, or omission of a significant part of the required decompression (decompression obligation), a severe decompression accident (SDA) may occur. Serious permanent disability and a high risk of fatality is expected in the event of an SDA. It is not known whether existing treatment tables can adequately deal with the expected outcome from such an accident.

In the event that an SDA does occur, survival will depend largely upon the severity and adversity of the physiological and structural changes which are incurred by the diver as a result of the dive profile, rate of ascent and treatment responses on the surface.

While immediate or rapid recompression on the surface is expected to provide the greatest benefit and relief in conjunction with standard accepted procedures, such as the administration of surface oxygen and intravenous fluid, it is not well known whether or not it is necessary or important to recompress the diver to a depth equal to, or greater than the depth of the incident dive.

Recompression to depths greater than the incident dive and the use of breathing gas mixtures other than those specified by in-service Canadian Armed Forces (CF) treatment tables may be required to adequately treat the diver. The current accepted belief among some diving medicine professionals is that uncontrolled, rapid ascent must be treated by recompressing the diver to the depth of the incident dive plus one atmosphere of pressure. Thus, a CUMA dive to the maximum depth or 81 msw would require recompression to 90 msw for effective treatment. Most CF treatment facilities, on the other hand, are capable of treating to a maximum depth of only 69 msw. In addition, these deep treatment procedures may require more gas, personnel and supplies than existing treatment facilities can supply.

Whether or not it is necessary to recompress to a depth which exceeds the maximum depth of the dive plus one atmosphere of pressure for the treatment of SDA is unknown. It may be possible to recompress to a

lesser pressure, administer raised partial pressure of oxygen, and apply adjunctive agents to effectively and efficiently treat serious decompression accidents. A review by the US Navy of the use of USN Treatment Table 6 and USN Treatment Table 6A for suspected arterial gas embolism did not demonstrate a greater benefit in the use of the deeper table (1).

Present Option

CF Treatment Table 8 for “deep blow up” may begin as deep as 225 feet of seawater and lasts for 56 hours and 29 minutes. The use of this table places high demands on the treating facility for personnel, equipment and breathing gases. In addition, many chamber personnel are unfamiliar and inexperienced in the use of this treatment option.

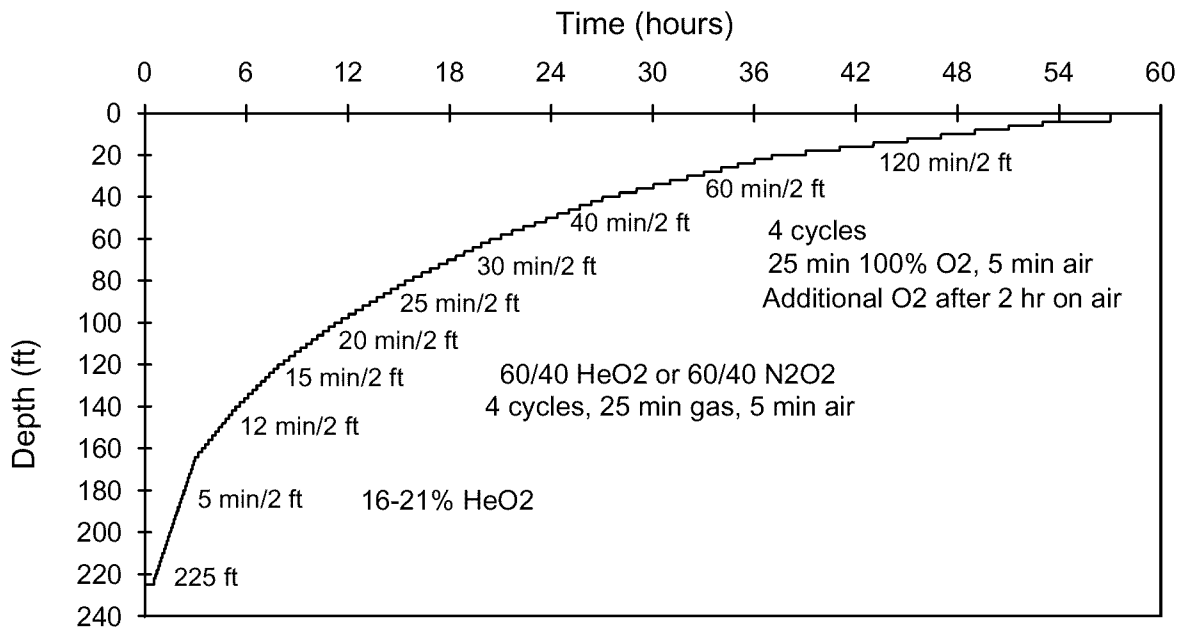


Figure 1. CF Treatment Table 8 for blowup from deep HeO₂ dives

Evaluation of Treatment Options

The risk of serious and permanent injury following SDA precludes the experimental use of divers in the evaluation of treatment table option. Therefore, it is necessary to explore other useful options for the evaluation of treatment tables. A mathematical model of human physiology, gas dynamics and bubble growth in response to pressure changes provides one means by which treatment table effectiveness in reducing and clearing inert gases may be evaluated. Although the presence of bubbles in a physiological model does not represent decompression illness *per se*, it is generally accepted by most diving medicine researchers and clinicians that the presence of more bubbles, especially of greater dimension and higher volume, can correlate with a higher incidence of decompression illness.

A preliminary study of CF Table 8 showed that it is inappropriate for use in SDA; although it removed bubbles from SDA very quickly, it also generated bubbles in the slowest tissues later on, thereby creating an additional decompression problem towards the end of the treatment schedule. Subsequent evaluations of other alternative treatment tables suggested that shallower, shorter tables such as USN Treatment Table 6 (CF TT6, maximum depth 18.2 msw, total elapsed time of 4 hours and 46 minutes) and USN Treatment

Table 6A (CF TT6A, initial recompression to 50 msw, total elapsed time of 5 hours and 54 minutes) did not inherently generate more inert gas, and yet were effective in reducing bubbles generated by SDA.

A review of case studies (SDA) may provide some insights into the effectiveness of treatments used. Databases were reviewed at DCIEM (representing CF diving incident and accident cases over the previous ten years) and from NEDU, Panama City, Florida (representing treatments provided from 1985 to 1995). Also, a limited number of commercial and civilian cases were reviewed. Fewer than ten cases could be identified as representing SDA from these databases. Information derived was not deemed sufficiently specific enough in most cases to provide any useful conclusions in evaluating the effectiveness of treatment options used.

An important modality for evaluating the effectiveness of treatment options involves the use of a suitable animal model. Animal studies were conducted using live, anaesthetized pigs at the SINTEF Unimed Norway in association with Unimed Scientific Limited. Treatment Tables 6 and 6A were selected for evaluation since the theoretical work had suggested that they might be the best tables for SDA. In addition, they are already well known internationally and represent standard treatment tables which can be readily carried out on-site during minecountermeasures (MCM) operations. Effective treatment of SDA with either of these tables represents a considerable advantage by reducing required treatment hours and pressurization, thereby reducing the overall volume of required treatment gas, manpower and need for specialized equipment. This represents a significant operational advantage for the Canadian Armed Forces and international diving communities.

Conclusions

The Canadian Armed Forces use of CUMA for deep helium-oxygen diving in MCM and other operational diving missions, such as “Operation Persistence,” the recovery of SwissAir 111 in 1998, requires that treatment options be reviewed in the event of Severe Decompression Accidents (SDA).

It may be possible to effectively treat SDA with shallower, shorter treatment tables such as USN TT6 or USN TT6A.

The evaluation of treatment table options in this study consists of a mathematical model of inert gas dynamics and the use of a pig model to provide a live, physiological model of SDA and treatment table effectiveness.

Further studies, using the animal model, may include testing of more treatment tables (e.g., RN 67), the use of adjunctive therapies such as intravenous rehydration with saline or perfluorocarbons, the use of a “drogue” device to slow the rate of ascent, pathological analysis of the pig model to investigate pulmonary and neuroanatomical sequelae, monitoring of jugular vein bubbles using doppler probes, and the review of in-water recompression options.

References

Howsare CR, Rocca AF, Morrison LJ, Jackson RL. Comparison of TT6 vs TT6A for the treatment of AGE in the US Navy, a retrospective study. *Undersea Hyperbaric Med* 1997; 24(Supplement): 33.

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